



**Aerospace
Systems Division**

ALSEP FASTNER
REDUCTION STUDY

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| NO. | REV. NO. |
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| PAGE _____ | OF _____ |
| DATE October 17, 1968 | |

FINAL REPORT
ALSEP FASTNER
REDUCTION STUDY

Submitted in Partial
Fulfillment of Requirements
of CCP 90

Prepared by: J. H. Owens, Jr.

Approved by: M. Katz

M. Katz, Group Engineer
ALSEP Structural/Thermal Engineering

ALSEP Sunshield Pallet

Fastener Tie Down Investigation

1.0 SCOPE

This report covers a design and analysis investigation of the ALSEP compartment #1 sunshield pallet fastener tie down system, with the purpose of reducing the number of fasteners that the astronaut must release at time of deployment.

2.0 REFERENCES

- (1) Drawing No. BSX 7517 ALSEP Revised Fastener and Pin Pattern - Sunshield Pallet
- (2) Drawing No. BSX 7518 ALSEP Revised Fastener and Pin Pattern - Thermal Plate and Primary Structure
- (3) Introduction to Matrix Methods of Structural Analysis - H. C. Martin, McGraw Hill Book Company.
- (4) Interdepartmental Memo 68-210-24M "ALSEP Compartment #1 Fasteners Reduction Study"
- (5) Interdepartmental 68-210-37M "Summary Report of Changes to ALSEP Structure to make Smaller Number of Fasteners Possible."
- (6) Internal Memorandum 1/17/68 to T. Fenske from J. Maszatics, D. Dewhirst, Subject: ALSEP Safety Factors and Limit Load Factors.
- (7) "Dynamics of Structures" - Walter C. Hurty, Moshe F. Rubinstein, Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- (8) Drawing No. 2330203 - Primary Structure Assembly
- (9) Drawing No. 2330301 - Basic Assembly Primary Structure
- (10) Drawing No. 2335161 - Sunshield Sub-Package No. 1
- (11) Tridair Industries Drawing CA 2773, Bolt Positive Locking Quick Release

- (12) Bulletin No. 118 and 119 , "Analysis of Flat Plates by the Algebraic Carry Over Method" - Tuma and Havner, Oklahoma State University.

3.0 SUMMARY

It is concluded that the fasteners around the edge of the pallet can be reduced from sixteen to nine and one of the center fasteners can be removed with a weight increase of approximately 1.75#. Modifications as shown on references (1) and (2) would have to be made to the structure.

The following changes outlined in references (4) and (5) are repeated here for convenience:

Sunshield Pallet Ref. (1)

1. 0.020 aluminum reinforcing doublers added to top and bottom of pallet around edge.
2. Twelve taper pins added around edge of pallet.
3. Location of corner fasteners changed to attach to attach to inner flange rather than outer flange.
4. Front edge member or beam changed from 0.050 to 0.070.
5. Necessary changes made to pallet to relocate fasteners.

Thermal Plate and Primary Structure - Ref. (2)

1. Locally upper flange of primary structure has been increased to 0.25" at each fastener and to 0.125" at each pin.
2. Inner corner flanges are increased to 0.25".
3. Changes to edge of thermal plate to accommodate pin and fastener locations are necessary.

In general, materials, type of hardware, etc. have been kept the same as existing structure. No attempt has been made to refine or change existing design except as necessary for the fastener change.

Preload on each fastener should be the maximum within the limits of the astronaut to apply.

4.0 ANALYSIS

4.1 Discussion

The analysis conducted in this study was done to determine whether the changes and modifications as proposed would deleteriously effect the dynamic characteristics of the ALSEP structure and whether acceleration transmissibilities would be increased.

In general it can be shown that deflections of the sun-shield pallet will not be more severe after removing the fasteners then they were with fasteners and that no serious increases in transmissibilities are to be expected. Also based on Ref. (6) dynamic inputs to ALSEP are reduced from those originally used for design.

The following pages of calculations obtain deflections for an assumed unit load of 1# per inch along each edge and comparing the existing pallet to the modified design. Deflections for the modified design compare favorably to the existing design.

The following changes were made which affect the dynamic characteristics.

1. Local pads are placed at each fastener attaching point on primary structure. This markedly reduces flange deflections particularly along the front (Beam 3).
2. Edge members of pallet have been reinforced by adding a 0.020 doubler around the edge top and bottom. This reduces deflections between fasteners and results in the pallet behaving more like a plate supported uniformly around the edge rather than as a plate supported at a series of concentrated points.

This was deemed advisable due to the reduction of the number of fasteners.

3. Fasteners in center were reduced from three to two. This has little effect on the pallet deflections or thermal plate. Thermal plate deflections are further alleviated by taper pins which prevent movement.

4.2 Analysis Procedure

4.2.1 Pallet Edge Members

Each pallet edge member was assumed to be a continuous beam with a unit load of 1#/in acting up along the beam. Each fastener was assumed to be a support point. These support points deflected under load due to bending, of the flange of the lower beam, deflection of the lower beam and elongation of the fastener. This investigation showed that deflection of the lower structure flange was much the greatest cause of pallet movement.

Given the EI's of the beams and AE's of fasteners the deflections of the upper beam were determined for the existing pallet, for the pallet without edge reinforcing for beams 1 and 2 and with reinforcing for beams 1, 2 and 3. (see pages 6).

Final deflection curves are given on pages 32-34 incl. No deflection curves are shown for beams 4 and 5 since these deflections are far less than other beams.

A study of deflection curves shows that with the new fastener, pattern deflections would be equal to or below existing deflections and no pronounced increase in transmissibilities are to be expected.

The procedure for preforming this was originally set up using Castigliano's Least Work equations (pages 13-15 incl.). However a computer program available at Bendix Aerospace Systems Division based on a matrix method given in References (3) and (7) was found applicable and saved considerable labor.

The basic matrix relationships are from ref. (7) and are as follows:

$$\begin{aligned} \begin{Bmatrix} \delta \end{Bmatrix} &= \begin{bmatrix} \beta \end{bmatrix} \begin{bmatrix} K \end{bmatrix}^{-1} \begin{Bmatrix} Q \end{Bmatrix} \\ \begin{Bmatrix} P \end{Bmatrix} &= \begin{bmatrix} K \end{bmatrix} \begin{bmatrix} \beta \end{bmatrix} \begin{bmatrix} K \end{bmatrix}^{-1} \begin{Bmatrix} Q \end{Bmatrix} \\ \begin{Bmatrix} \delta \end{Bmatrix} &= \text{matrix for element deflections and rotations} \\ \begin{bmatrix} \beta \end{bmatrix} &= \text{displacement compatibility matrix which insures the connectivity of the system} \\ \begin{bmatrix} K \end{bmatrix} &= \text{stiffness coefficient matrix} \\ \begin{Bmatrix} Q \end{Bmatrix} &= \text{matrix of applied forces} \\ \begin{Bmatrix} P \end{Bmatrix} &= \text{internal force matrix.} \end{aligned}$$

Detail procedures for determining these matrices are also discussed in Ref. (3). Pages 13-16 incl give a sample procedure.

Primary deflections were due to movements at attachment points. Deflections were also computed between points of support and are included in the deflection curves. These deflections turn out to be relatively small.

4.2.2 Pallet

The pallet was investigated to determine the effect of removing one center fastener. Referring to pages 34-39 incl. fastener A was removed and the load carried by this fastener was distributed equally to fasteners B and C.

Using tables given in Ref. (12) it was shown on the curves pages 38, 39 that this had no appreciable effect on deflections.

4.2.3 Thermal Plate

The thermal plate, although one center fastener has been removed, should be more satisfactory than the previous design. The regularly spaced taper pins, at closer tolerances, should reduce plate deflection. Based on the results of this investigation the third fastener was contributing little to plate deflection.

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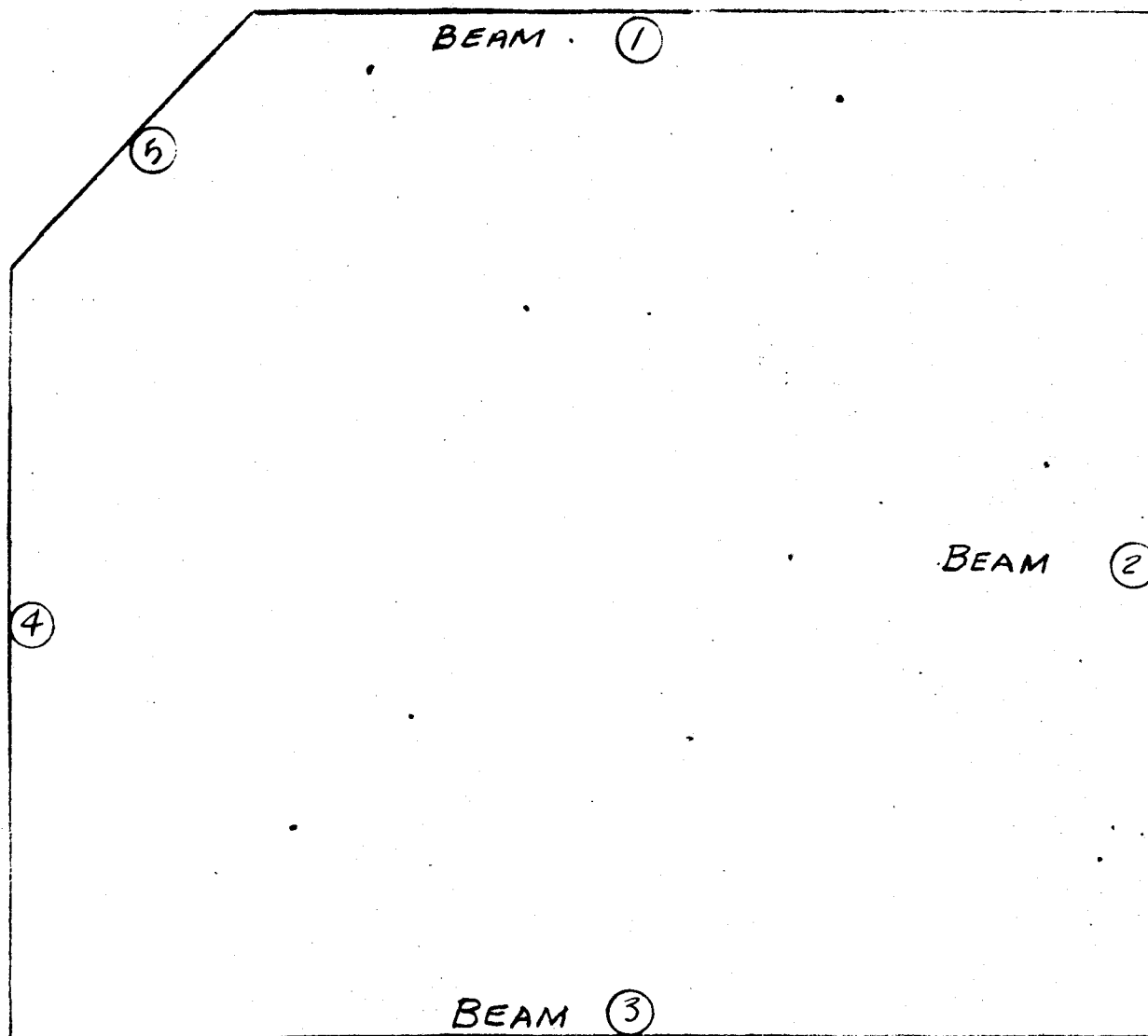
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PLAN OF SUNSHIELD PALLET
SHOWING LOCATION OF EDGE MEMBERS

SEE REF (1) DWG. BSX 7517 FOR FASTENER LOCATIONS.

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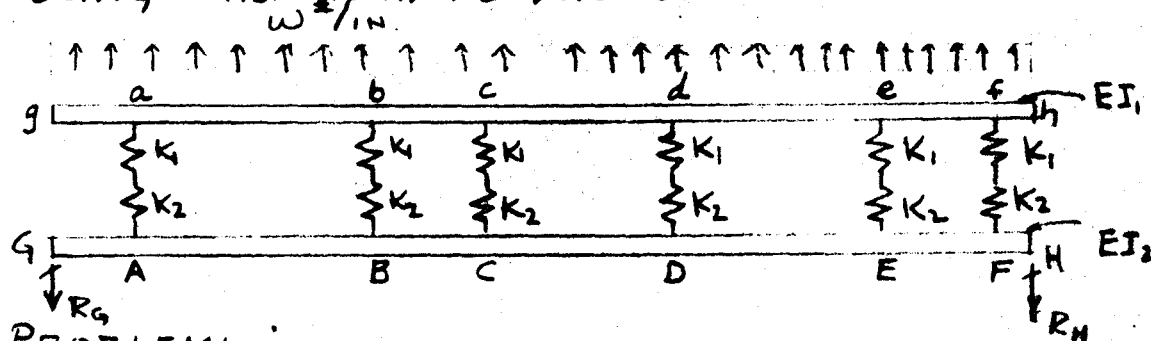


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UNIT MOMENTS & DEFLECTIONS FOR EDGE MEMBERS
 USING CASTIGLIANO'S THEOREM OF LEAST WORK



PROBLEM:

GIVEN: LOADING OF w /IN. UNIFORM ON gh .

DETERMINE MOMENTS & DEFLECTIONS OF gh & GH .

ASSUMING VALUES OF EI_1 , EI_2 , K_1 AND K_2

DIMENSIONS $a, b, c, \text{ETC.}$ WILL VARY

TAKE P_{bb} , P_{cc} , P_{dd} , P_{ee} AS REDUNDANTS

I DETERMINE P_{aA} & P_{fF} IN TERMS OF w & REDUNDANTS

$$(1) P_{aA} = wgh \left(\frac{\overline{gh}}{2} - \overline{fh} \right) - P_{bB} \left(\frac{\overline{bf}}{\overline{af}} \right) - P_{cC} \left(\frac{\overline{cf}}{\overline{af}} \right) - P_{dD} \left(\frac{\overline{df}}{\overline{af}} \right) - P_{eE} \left(\frac{\overline{ef}}{\overline{af}} \right)$$

$$(2) P_{fF} = wgh \left(\frac{\overline{gh}}{2} - \overline{ga} \right) - P_{bB} \left(\frac{\overline{ab}}{\overline{af}} \right) - P_{cC} \left(\frac{\overline{ac}}{\overline{af}} \right) - P_{dD} \left(\frac{\overline{ad}}{\overline{af}} \right) - P_{eE} \left(\frac{\overline{ae}}{\overline{af}} \right)$$

$$(3) R_g = P_{aA} \left(\frac{\overline{AH}}{\overline{GH}} \right) + P_{bB} \left(\frac{\overline{BH}}{\overline{GH}} \right) + P_{cC} \left(\frac{\overline{CH}}{\overline{GH}} \right) + P_{dD} \left(\frac{\overline{DH}}{\overline{GH}} \right) + P_{eE} \left(\frac{\overline{EH}}{\overline{GH}} \right) + P_{fF} \left(\frac{\overline{FH}}{\overline{GH}} \right)$$

$$(4) R_H = P_{aA} \left(\frac{\overline{GA}}{\overline{GH}} \right) + P_{bB} \left(\frac{\overline{GB}}{\overline{GH}} \right) + P_{cC} \left(\frac{\overline{GC}}{\overline{GH}} \right) + P_{dD} \left(\frac{\overline{GD}}{\overline{GH}} \right) + P_{eE} \left(\frac{\overline{GE}}{\overline{GH}} \right) + P_{fF} \left(\frac{\overline{GF}}{\overline{GH}} \right)$$

SUBSTITUTE (1) IN (3) AND (4)

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UNIT MOMENTS & DEFLECTIONS FOR EDGE MEMBERS

II MOMENT RELATIONSHIPS FOR gh

$$(5) M_{ga} = \frac{\omega x^2}{2}$$

$$(6) M_{ab} = \frac{\omega \bar{g}a^2}{2} + \frac{\omega x^2}{2} + (\omega \bar{g}a - P_{aA})x$$

$$(7) M_{bc} = \frac{\omega \bar{g}b^2}{2} - P_{aA} \bar{a}b + \frac{\omega x^2}{2} + (\omega \bar{g}b - P_{aA} - P_{bB})x$$

$$(8) M_{cd} = \frac{\omega \bar{g}c^2}{2} - P_{aA} \bar{a}c - P_{bB} \bar{b}c + \frac{\omega x^2}{2} + (\omega \bar{g}c - P_{aA} - P_{bB} - P_{cC})x$$

$$(9) M_{de} = \frac{\omega \bar{g}e^2}{2} - P_{aA} \bar{a}d - P_{bB} \bar{b}d - P_{cC} \bar{c}d + \frac{\omega x^2}{2} + (\omega \bar{g}d - P_{aA} - P_{bB} - P_{cC} - P_{dD})x$$

$$(10) M_{fe} = \frac{\omega \bar{h}f^2}{2} + \frac{\omega x^2}{2} + (\omega \bar{h}f - P_{fF})x$$

$$(11) M_{hf} = \frac{\omega x^2}{2}$$

SUBSTITUTE VALUES OF P_{aA} & P_{fF} FROM EQ. (1) AND (2)

IN (6) THRU (10) INCLUSIVE.

III MOMENT RELATIONSHIPS FOR GH

$$(12) M_{GA} = -R_g x$$

$$(13) M_{AB} = -R_g \bar{GA} + (-R_g + P_{aA})x$$

$$(14) M_{BC} = -R_g \bar{GB} + P_{aA} \bar{AB} + (P_{aA} + P_{bB} - R_g)x$$

$$(15) M_{CD} = -R_g \bar{AC} + P_{aA} \bar{AC} + P_{bB} \bar{BC} + (P_{aA} + P_{bB} + P_{cC} - R_g)x$$

$$(16) M_{DE} = -R_g \bar{AD} + P_{aA} \bar{AD} + P_{bB} \bar{BD} + P_{cC} \bar{CD} + (P_{aA} + P_{bB} + P_{cC} + P_{dD} - R_g)x$$

$$(17) M_{HE} = -R_h x$$

$$(18) M_{FE} = -R_D \bar{HF} + (-R_D + P_{fF})x$$

SUBSTITUTE VALUES (1), (2), (3) & (4) IN (12) THRU (18) INCL.

$$(19) K_3 = \frac{K_1 K_2}{K_1 + K_2}$$

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UNIT MOMENTS & DEFLECTIONS FOR EDGE MEMBERS

II LEAST WORK EQUATION

$$(20) \quad W = \frac{1}{2EI_1} \left[\int_a^b (M_{ga})^2 dx + \int_a^b (M_{ab})^2 dx + \int_b^c (M_{bc})^2 dx + \int_c^d (M_{cd})^2 dx \right. \\
 + \int_d^e (M_{de})^2 dx + \int_f^e (M_{fe})^2 dx + \left. \int_h^f (M_{fh})^2 dx \right] + \frac{1}{2EI_2} \left[\int_G^A (M_{GA})^2 dx + \int_A^B (M_{AB})^2 dx \right. \\
 + \int_B^C (M_{BC})^2 dx + \int_C^D (M_{CD})^2 dx + \int_D^E (M_{DE})^2 dx + \int_F^E (M_{FE})^2 dx + \left. \int_C^D (M_{HF})^2 dx \right] \\
 + \frac{1}{2K_3} \left[\overline{P}_{aA}^2 + \overline{P}_{bB}^2 + \overline{P}_{cC}^2 + \overline{P}_{dD}^2 + \overline{P}_{eE}^2 + \overline{P}_{fF}^2 \right]$$

SUBSTITUTE EQUATIONS (1), (2), (5) THRU (11) INCL; AND
 (12) THRU (18) INCL. IN EQ. (20)

V OBTAIN THE FOLLOWING PARTIAL DIFFERENTIATIONS OF (20), INTEGRATE AND EQUATE TO ZERO.

$$(21) \quad \frac{\partial W}{\partial P_{bB}} = 0 \quad (22) \quad \frac{\partial W}{\partial P_{cC}} = 0 \quad (23) \quad \frac{\partial W}{\partial P_{dD}} = 0 \quad (24) \quad \frac{\partial W}{\partial P_{eE}} = 0$$

VI FIND P_{aA} , P_{bB} , P_{cC} , P_{dD} , P_{eE} , P_{fF} , R_g AND H USING EQUATIONS (1), (2), (3), (4), (21), (22), (23), (24)

DETERMINE BENDING MOMENTS USING EQUATIONS (5) THRU (11)
 AND (12) THRU (18) FOR $x = 0$, $x = \frac{ab}{2}$, $\frac{AB}{2}$, $\frac{bc}{2}$, $\frac{BC}{2}$ ETC.
 AND FOR $x = ab$, AB , bc , BC ETC.

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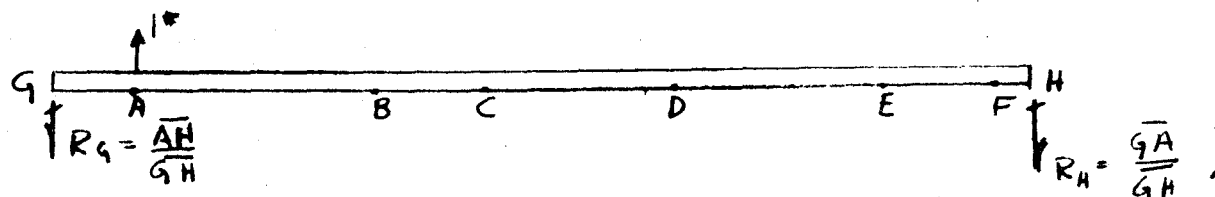
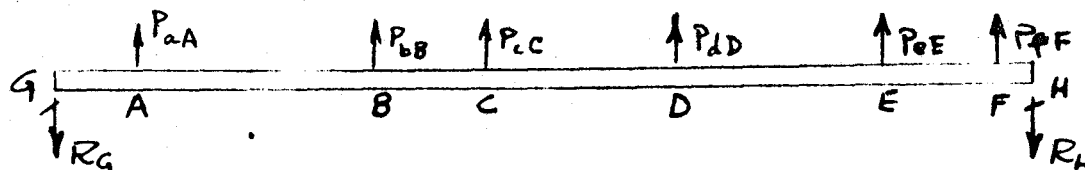
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UNIT MOMENTS & DEFLECTIONS FOR EDGE MEMBERS

VII DEFLECTIONS ~ BEAM AB

DEFLECTION AT A " δ_A ".



$$(25) \quad m_{GA} = -\frac{\overline{AH}}{\overline{GH}} x$$

$$(26) \quad m_{AB} = -\frac{\overline{AH}}{\overline{GH}} \overline{GA} + \left(1 - \frac{\overline{AH}}{\overline{GH}}\right) x$$

$$(27) \quad m_{BC} = -\frac{\overline{AH}}{\overline{GH}} \overline{GA} + \left(1 - \frac{\overline{AH}}{\overline{GH}}\right) (AB + x)$$

$$(28) \quad m_{CD} = -\frac{\overline{AH}}{\overline{GH}} \overline{GA} + \left(1 - \frac{\overline{AH}}{\overline{GH}}\right) (AC + x)$$

$$(29) \quad m_{DE} = -\frac{\overline{AH}}{\overline{GH}} \overline{GA} + \left(1 - \frac{\overline{AH}}{\overline{GH}}\right) (AD + x)$$

$$(30) \quad m_{FE} = -\frac{\overline{GA}}{\overline{GH}} (\overline{HF} + x)$$

$$(31) \quad m_{HF} = -\frac{\overline{GA}}{\overline{GH}} x$$

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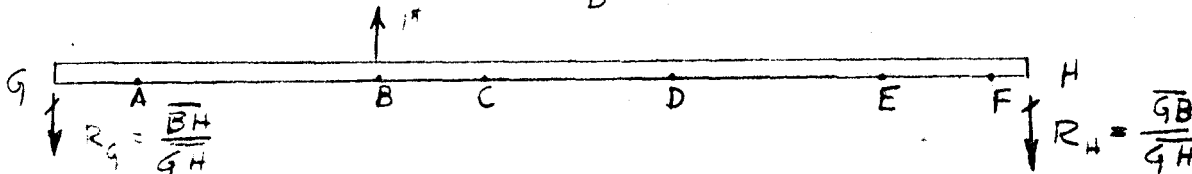
UNIT MOMENTS & DEFLECTIONS FOR EDGE MEMBERS

IV DEFLECTIONS ~ BEAM AB (CONTINUED)

$$(32) \delta_A = \frac{1}{EI_2} \left[\int_G^A M_{GA} m_{GA} dx + \int_A^B M_{AB} m_{AB} dx + \int_B^C M_{BC} m_{BC} dx + \int_C^D M_{CD} m_{CD} dx \right. \\ \left. + \int_D^E M_{DE} m_{DE} dx + \int_E^F M_{FE} m_{FE} dx + \int_F^H M_{HF} m_{HF} dx \right]$$

SUBSTITUTE EQUATIONS (12) THRU (18) INCLUSIVE AND (25) THRU (31) INCLUSIVE TO FIND DEFLECTIONS AT A.

DEFLECTION AT B " δ_B "



$$(33) m_{GA} = -\frac{BH}{GH} x$$

$$(34) m_{AB} = -\frac{BH}{GH} \overline{GB} - \frac{BH}{GH} x$$

$$(35) m_{BC} = -\frac{BH}{GH} \overline{GB} + \left(1 - \frac{BH}{GH}\right) x$$

$$(36) m_{CD} = -\frac{BH}{GH} \overline{GC} + \left(-\frac{BH}{GH}\right)(\overline{BC} + x)$$

$$(37) m_{DE} = -\frac{BH}{GH} \overline{GC} + \left(-\frac{BH}{GH}\right)(\overline{BD} + x)$$

$$(38) m_{FE} = -\frac{GB}{GH} (\overline{HF} + x)$$

$$(39) m_{HF} = -\frac{GB}{GH} x$$

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VII DEFLECTIONS ~ BEAM AB (CONTINUED)

$$(40) \delta_B = \frac{1}{EI_2} \left[\int_G^A M_{GA} m_{GA} dx + \int_A^B M_{AB} m_{AB} dx \right] \dots$$

FOLLOW THRU IN SAME MANNER AS δ_A USING m FOR δ_B .

IN LIKE MANNER OBTAIN DEFLECTIONS FOR C, D, E, & F

VIII DEFLECTIONS ~ BEAM ab

$$\delta_a = \delta_A + \frac{P_{aA}}{K_3}$$

$$\delta_c = \delta_C + \frac{P_{cC}}{K_3}$$

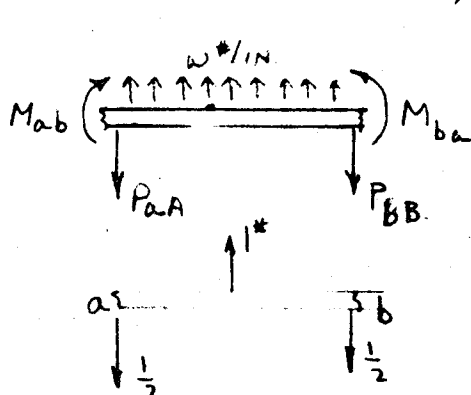
$$\delta_e = \delta_E + \frac{P_{eE}}{K_3}$$

$$\delta_b = \delta_B + \frac{P_{bB}}{K_3}$$

$$\delta_d = \delta_D + \frac{P_{dD}}{K_3}$$

$$\delta_f = \delta_F + \frac{P_{fF}}{K_3}$$

DEFLECTIONS MIDWAY BETWEEN SUPPORTS



$$\delta_{ab} = \frac{1}{EI_1} \left[\int_0^{ab} \left(M_{ab} + \frac{wx^2}{2} - P_{aA}x \right) \frac{x}{2} dx \right. \\ \left. + \int_0^{ba} \left(M_{ba} + \frac{wx^2}{2} - P_{bB}x \right) \frac{x}{2} dx \right]$$

IN LIKE MANNER DETERMINE DEFLECTIONS AT OTHER MIDPOINTS ALONG BEAM gh.

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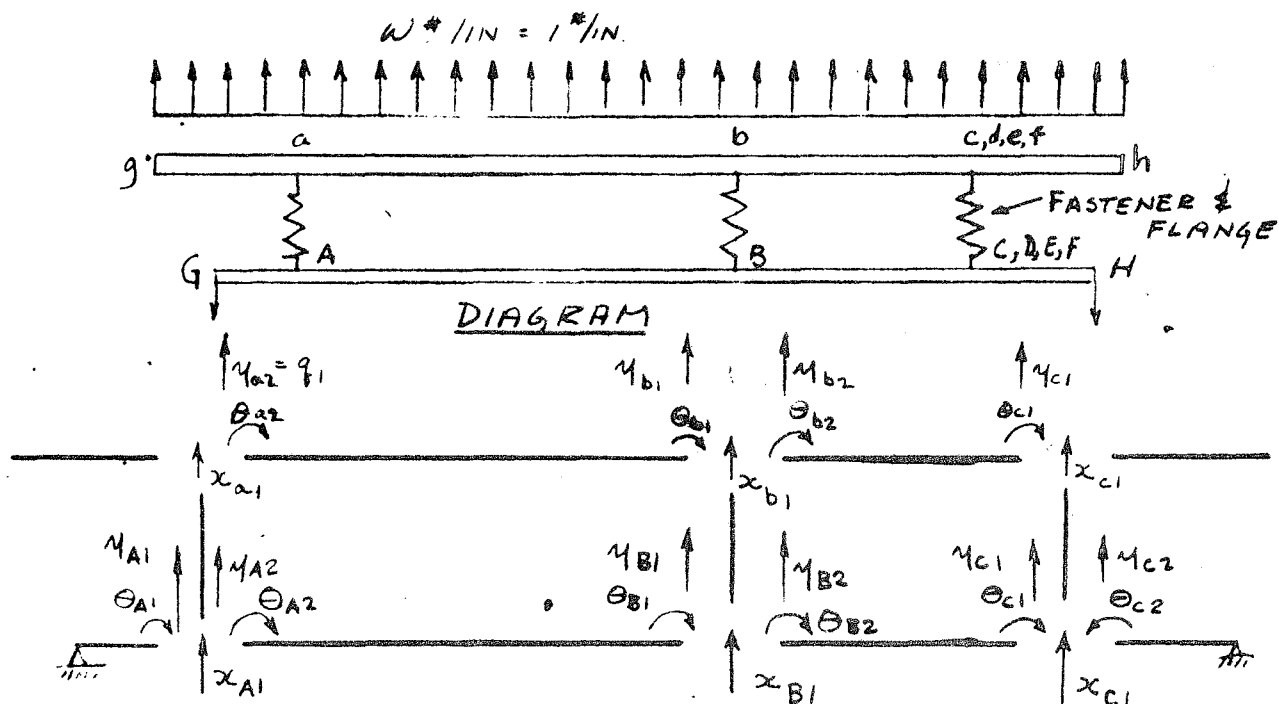
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LOADS AND DEFLECTIONS OF EDGE MEMBERS

SAMPLE COMPUTER INPUT MATRICES

BEAM 1 - EXISTING PALLET



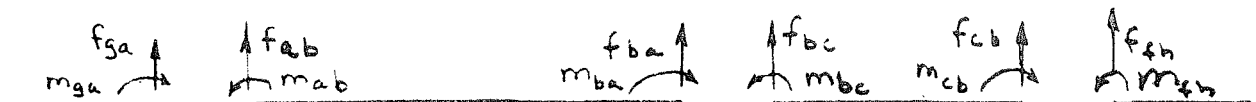
NOMENCLATURE

y = BEAM DEFLECTIONS

x = FASTENER MOVEMENTS

θ = BEAM ROTATIONS

BEAM ELEMENTS



UPPER BEAM - gh ~ LOADING

REF. (3) SECT. 4.22

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LOADS & DEFLECTIONS OF EDGE MEMBERS
 SAMPLE COMPUTER INPUT MATRICES (CONTINUED)
 BEAM 1 EXISTING PALLET

B MATRIX (REF. 7 PAGE 40)

| No* | R _i | q ₁ | q ₂ | q ₃ | q ₄ | q ₅ | q ₆ | q ₇ | q ₈ | q ₉ | q ₁₀ | q ₁₁ | q ₁₂ |
|-----|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|
| 1 | M _{A2} | 1 | | | | | | | | | | | |
| 2 | Θ _{A2} | | 1 | | | | | | | | | | |
| 3 | M _{B1} | | | 1 | 1 | | | | | | | | |
| 4 | Θ _{B1} | | | | 1 | | | | | | | | |
| 5 | M _{B2} | | | 1 | | | | | | | | | |
| 6 | Θ _{B2} | | | | 1 | | | | | | | | |
| 7 | M _{C1} | | | | | 1 | | | | | | | |
| 8 | Θ _{C1} | | | | | | 1 | | | | | | |
| 9 | X _{A1} | | | | | | | 1 | | | | | |
| 10 | X _{A2} | 1 | | | | | | | | | | | |
| 11 | X _{B1} | | | | | | | | | 1 | | | |
| 12 | X _{B2} | | | 1 | | | | | | | | | |
| 13 | X _{C1} | | | | | | | | | | | 1 | |
| 14 | X _{C2} | | | | | 1 | | | | | | | |
| 15 | M _{A1} | | | | | | | 1 | | | | | |
| 16 | Θ _{A1} | | | | | | | | 1 | | | | |
| 17 | M _{A2} | | | | | | | 1 | | | | | |
| 18 | Θ _{A2} | | | | | | | | 1 | | | | |
| 19 | M _{B1} | | | | | | | | | 1 | | | |
| 20 | Θ _{B1} | | | | | | | | | | 1 | | |
| 21 | M _{B2} | | | | | | | | | | | 1 | |
| 22 | Θ _{B2} | | | | | | | | | | | | 1 |
| 23 | M _{C1} | | | | | | | | | | | | 1 |
| 24 | Θ _{C1} | | | | | | | | | | | | |
| 25 | M _{C2} | | | | | | | | | | | | |
| 26 | Θ _{C2} | | | | | | | | | | | | -1 |

* NO. REFERS TO COMPUTER OUTPUT DATA

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LOADS AND DEFLECTIONS OF EDGE MEMBERS

SAMPLE COMPUTER INPUT MATRICES ~ K MATRIX

THE $[K]$ MATRIX IS MADE UP OF THE ELEMENTAL
 STIFFNESS MATRICES $[k]$ REF (T) PG. 41

$$[K] = \begin{bmatrix} [k_{ab}] & & & & & & & \\ & [k_{bc}] & & & & & & \\ & & [k_{aA}] & & & & & \\ & & & [k_{bB}] & & & & \\ & & & & [k_{cC}] & & & \\ & & & & & [k_{GA}] & & \\ & & & & & & [k_{AB}] & \\ & & & & & & & [k_{BC}] \\ & & & & & & & & [k_{FH}] \end{bmatrix} \quad (\text{ELEMENTS NOT SHOWN} = 0)$$

$[k]$ FOR BEAMS ab, bc, AB, BC

$$[k] = \begin{bmatrix} \frac{12EI}{e^3} & -\frac{6EI}{e^2} & -\frac{12EI}{e^3} & -\frac{6EI}{e^2} \\ & \frac{4EI}{e} & \frac{6EI}{e^2} & \frac{2EI}{e} \\ (SYMM.) & & \frac{12EI}{e^3} & \frac{6EI}{e^2} \\ & & & \frac{4EI}{e} \end{bmatrix}$$

REF PAGES 27 & 28
 FOR VALUES

$[k]$ FOR BEAMS GA & FH ($M_G = 0, M_H = 0, \gamma_G = 0, \gamma_H = 0$)

$$[k] = \begin{bmatrix} \frac{3EI}{e^3} & \frac{3EI}{e^2} \\ (SYMM) & \frac{3EI}{e} \end{bmatrix}$$

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ALSEP FASTENER REDUCTION STUDY

LOADS AND DEFLECTIONS OF EDGE MEMBERS

SAMPLE COMPUTER INPUT MATRICES ~ K MATRIX (CONT.)

k FOR "SPRINGS" aA, bB, cC

$$[k] = \begin{bmatrix} K & K \\ K & K \end{bmatrix} \quad (\text{REF PAGE 25})$$

APPLIED FORCES MATRIX {Q}

$$\{Q\} = \begin{Bmatrix} Q_1 \\ Q_2 \\ Q_3 \\ Q_4 \\ Q_5 \\ Q_6 \\ Q_7=0 \\ Q_8=0 \\ Q_9=0 \\ Q_{10}=0 \\ Q_{11}=0 \\ Q_{12}=0 \end{Bmatrix}$$

$$Q_1 = f_{ga} + f_{ab} = \omega(ga) + \omega\left(\frac{ab}{2}\right)$$

$$Q_2 = +m_{ga} - \bar{m}_{ab} = \omega \frac{ga^2}{2} - \frac{\omega \bar{a}b^2}{12}$$

$$Q_3 = f_{ba} + f_{bc} = \omega\left(\frac{ba}{2}\right) + \omega\left(\frac{bc}{2}\right)$$

$$Q_4 = m_{ba} - m_{bc} = \frac{\omega b\bar{a}^2}{12} - \frac{\omega \bar{b}c^2}{12}$$

$$Q_5 = f_{cb} + f_{fh} = \omega\left(\frac{cb}{2}\right) + \omega(fh)$$

$$Q_6 = m_{cb} - m_{fh} = \frac{\omega \bar{c}b^2}{12} - \frac{\omega \bar{f}h^2}{2}$$

(REF. 3 PAR 4.22 PG. 124)

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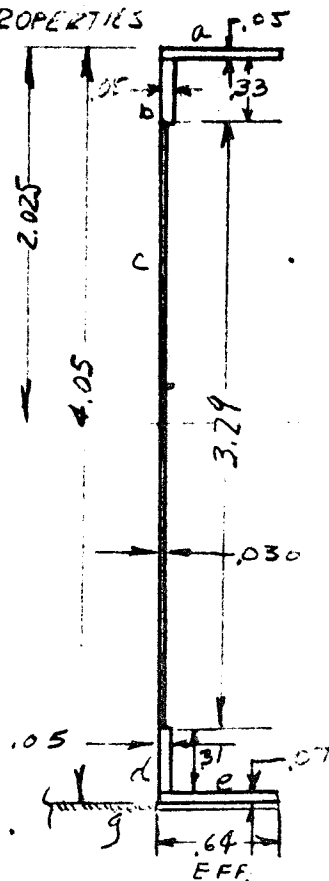
MODEL ALSEP

ALSEP FASTENER REDUCTION STUDY

BOX OR PRIMARY STRUCTURE - BEAMS 1 & 2

SECTION PROPERTIES

SIDE



| ITEM | A | h | Ah | Ah ² | I _o |
|------|--------|---------|--------|-----------------|----------------|
| a | .0320 | 2.000 | .0640 | .1280 | NEG. |
| b | .01605 | 1.8145 | .0291 | .0528 | .0002 |
| c | .09870 | 0 | 0 | 0 | .0890 |
| d | .01505 | -1.7945 | -.0270 | .0485 | .0002 |
| e | .04480 | -1.9900 | -.0892 | .1775 | NEG. |
| f | .20660 | -1.118 | -.0231 | .4068 | .0894 |

$$I = .4068 + .0894 - .2066(1.118)^2$$

$$= .4068 + .0894 - .0026 = .4936$$

INCLUDING BOTTOM SKIN

| ITEM | A | h | Ah | Ah ² | I _o |
|------|--------|---------|--------|-----------------|----------------|
| f | .20660 | -1.118 | -.0231 | .4068 | .0894 |
| g | .01280 | -2.0350 | -.0260 | .0529 | NEG. |
| h | .21940 | 2.238 | .0491 | .4597 | .0894 |

$$I = .4597 + .0894 - .2194(2.238)^2$$

$$.4597 + .0894 - .0110 = .5381$$

$$E = 10.3 \times 10^6$$

$$EI = .5381 \times 10.3 \times 10^6$$

$$= \underline{5.5424 \times 10^6}$$

REF. (8) & (9)

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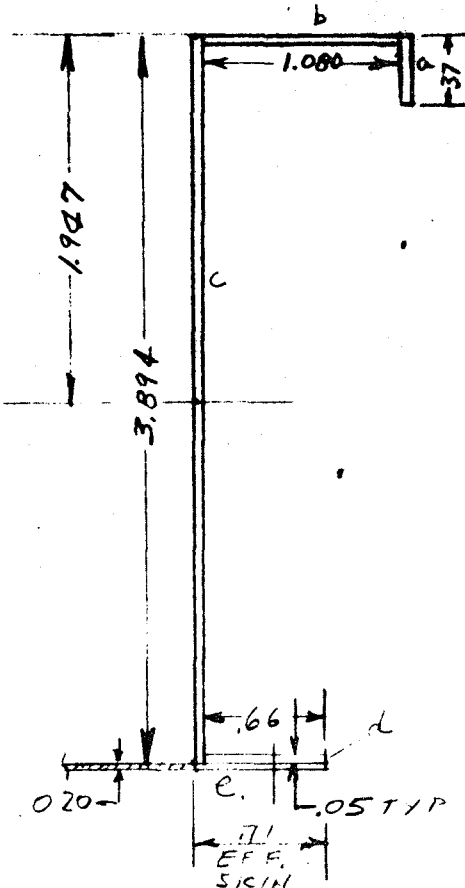
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MODEL ALSEP

ALSEP FASTENER REDUCTION STUDY

BOX OR PRIMARY STRUCTURE ~ FRONT ~ BEAM 3

SECTION PROPERTIES ~ REF (8) & (9)



| ITEM | A | h | Ah | Ah ² | I ₀ |
|------|-------|---------|---------|-----------------|----------------|
| a | .0185 | 1.7620 | .03260 | .05744 | .0002 |
| b | .0540 | 1.9220 | .10379 | .19948 | NEG. |
| c | .1947 | 0 | 0 | 0 | .2460 |
| d | .0330 | -1.9220 | -.06343 | .12191 | NEG. |
| e | .0140 | -1.9570 | -.02740 | .05362 | NEG. |
| | .3142 | .1450 | .04556 | .43245 | .2462 |

$$I = .43245 + .2462 - .3142(.1450)^2$$

$$= .6787 - .0066 = .6721$$

$$EI_2 = .6721 \times 10.3 \times 10^6$$

$$= \underline{\underline{6.9226 \times 10^6}}$$

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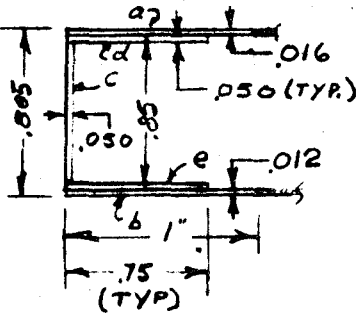
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PALLET EDGE MEMBER SECTION PROPERTIES

EXISTING PALLET & REVISION 1 BEAMS 1 & 2 (REF. 10)

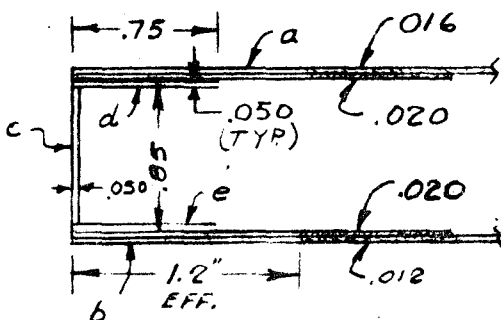


| ITEM | A | h | Ah | Ah ² | I _o |
|------|------|--------|---------|-----------------|----------------|
| a | .016 | .4345 | .00695 | .00302 | NEG. |
| b | .012 | -.4365 | -.00523 | .00229 | NEG. |
| c | .038 | 0 | 0 | 0 | .00175 |
| d | .038 | .4000 | .01520 | .00607 | NEG. |
| e | .038 | .4000 | -.01520 | .00607 | NEG. |
| Σ | .142 | .0121 | .00172 | .01745 | .00175 |

$$I = .01745 + .00175 = .01920$$

$$EI = .01920 \times 10.6 \times 10^6 = .2035 \times 10^6$$

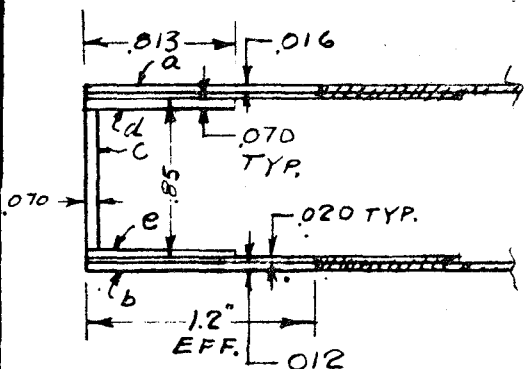
PALLET REVISION 2 BEAMS 1 & 2 ~ REF (1)



| ITEM | A | h | Ah | Ah ² | I _o |
|------|-------|--------|---------|-----------------|----------------|
| a | .0432 | .4430 | .01915 | .00850 | NEG. |
| b | .0375 | -.4410 | -.01655 | .00728 | NEG. |
| c | .0380 | 0 | 0 | 0 | .00175 |
| d | .0380 | .4000 | .01520 | .00608 | NEG. |
| e | .0380 | -.4000 | -.01520 | .00608 | NEG. |
| Σ | .1947 | .0133 | .00260 | .02794 | .00175 |

$$I = .02794 + .00175 = .02969 \quad EI = .02969 \times 10.6 \times 10^6 = .3150 \times 10^6$$

PALLET REVISION 1 & 2 BEAM 3 ~ REF (1)



| ITEM | A | h | Ah | Ah ² | I _o |
|------|-------|--------|---------|-----------------|----------------|
| a | .0432 | .4415 | .01907 | .008419 | NEG. |
| b | .0384 | -.4405 | -.01692 | .007451 | NEG. |
| c | .0497 | 0 | 0 | 0 | .00208 |
| d | .0570 | .3900 | .02223 | .008670 | NEG. |
| e | .0570 | -.3900 | -.02223 | .008670 | NEG. |
| Σ | .2453 | .0191 | .00215 | .03210 | .00208 |

$$I = .03210 + .00208 = .03418 \quad EI = 10.6 \times 10^6 \times .03418 = .3630 \times 10^6$$

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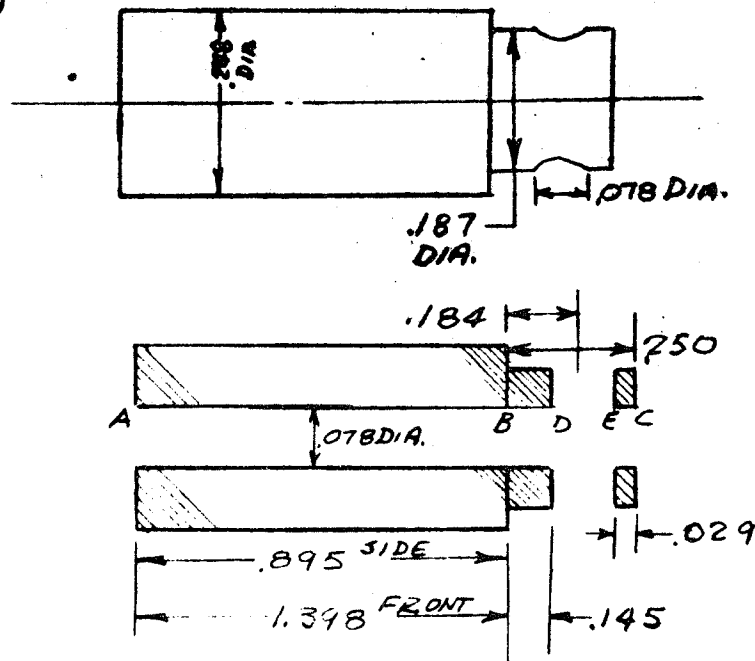
MODEL ALSEP

ALSEP FASTENER REDUCTION STUDY

POSITIVE LOCKING BOLT SPRING CONSTANT

REF. TRIDAIR INDUSTRIES D.W.G. CA2773

REF. (II)



SECTION AB ~ AREA

$$\left(\frac{.248^2 - .078^2}{4} \right) 3.14 = \left(\frac{.06150 - .00608}{4} \right) 3.14 = .04350 \text{ in}^2$$

$$\frac{AE}{L} = \frac{.0435 \times 29 \times 10^6}{.895} = 1,410,000 \text{ #/IN. SIDE BEAMS}$$

$$\frac{AE}{L} = \frac{.0435 \times 29 \times 10^6}{1.398} = 902000 \text{ #/IN. FRONT}$$

SECTION BD ~ EC

$$\text{AREA} = \left(\frac{.187^2 - .078^2}{4} \right) 3.14 = .0226 \text{ in}^2$$

$$\frac{AE}{L} = \frac{.0226 \times 29 \times 10^6}{.145} = 4.52 \times 10^6$$

$$\frac{AE}{L} = \frac{.0226 \times 29 \times 10^6}{.029} = 2.4 \times 10^6$$

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POSITIVE LOCKING BOLT SPRING CONSTANT
(CONTINUED)

SECTION DE

$$\text{AREA} = .0226 - .109 \times .078 = .0141 \text{ } \square \text{ } "$$

$$\frac{AE}{L} = \frac{.0141 \times 29 \times 10^6}{.078} = 5.25 \times 10^6$$

$$\frac{1}{K} = \frac{1}{10^6} \left[\frac{1}{1.41} + \frac{1}{4.52} + \frac{1}{24.4} + \frac{1}{5.25} \right] = \frac{1}{10^6} \left[\frac{579 + 180 + 334 + 155}{813} \right]$$

$$\frac{1}{K} = \left(\frac{11947.4}{813} \right) \times 10^{-6} \quad K_1 = \underline{\underline{860 \times 10^6}} \text{ SIDE}$$

$$\frac{1}{K} = \left[\frac{1}{9.02} + \frac{1}{4.52} + \frac{1}{24.4} + \frac{1}{5.25} \right] \frac{1}{10^6} = \left[\frac{579 + 116 + 214 + 99}{520} \right] \frac{1}{10^6}$$

$$\frac{1}{K} = \left(\frac{815.4}{520} \right) \frac{1}{10^6} \quad K_1 = \underline{\underline{640 \times 10^6}} \text{ FRONT}$$

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ALSEP FASTENER REDUCTION STUDY

LOWER STRUCTURE FLANGE SPRING CONSTANTS

NOTE:- SPRING CONSTANTS ARE APPROXIMATE, BUT CONSERVATIVE, AND SHOULD GIVE GOOD RELATIVE RELATIONSHIPS BETWEEN EXISTING FLANGES AND MODIFIED FLANGES.

EXISTING ALSEP SPRING CONSTANTS (REF. DWG. 2330301)

BEAMS 1 & 2 (SIDE & REAR) REF (1)

$$P_{ULT} = \frac{.69 F_{ty} t^2}{C} \text{ (REF. LOCKHEED STRESS MEMO #89)}$$

t = FLANGE THICKNESS C = ECCENTRICITY

$$P_{ULT} = \frac{.69 \times 54000 \times .050^2}{.375} = 248^{\#}$$

F_{ty} = 54000 FOR 7079
 FORGED BAR
 (REF. MIL HDBK 5A)

$$P_{YLD} = 165^{\#}$$

EFF. FLANGE WIDTH b $\frac{6 M_{YLD}}{b t^2} = F_{ty}$ $\frac{6 \times 165 \times .375}{b (.05)^2} = 54000$

$$b = \frac{6 \times 165 \times .375}{54000 \times .05^2} = 2.76" \quad \text{DEFL. } \delta = \frac{P C^3}{3 E I} = \frac{165 \times .375^3 \times 12}{3 \times 10.3 \times 10^6 \times 2.76 \times .05^3}$$

$$K_2 = \frac{165}{.00980} = 16900^{\#}/IN. \quad = .00980"$$

BEAM 3 (FRONT FLANGE) USE SAME REFERENCES AS ABOVE

$$P_{ULT} = \frac{.69 F_{ty} t^2}{C} = \frac{.69 \times 54000 \times .05^2}{.78} = 119^{\#} \quad P_{YLD} = 79.5^{\#}$$

EFF. FLANGE WIDTH b

$$\frac{6 M_{YLD}}{b t^2} = F_{ty} \quad \frac{6 \times 79.5 \times .78}{b (.05)^2} = 54000 \quad b = \frac{6 \times 79.5 \times .78}{54000 \times .05^2} = 2.76"$$

$$\text{DEFL. } \delta = \frac{P C^3}{3 E I} = \frac{79.5 \times .78^3 \times 12}{3 \times 10.3 \times 10^6 \times 2.76 \times .05^3} = .0426"$$

$$K_2 = \frac{79.5}{.0426} = 1870^{\#}/IN.$$

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LOWER STRUCTURE FLANGE SPRING CONSTANTS (CONT.)
 REVISED STRUCTURE (REF. DWG. BSX7518) (REF. 2)
 BEAMS 1 & 2 (SIDE & REAR)

FLANGE THICKNESS $t = .25"$

$$P_{ULT.} = \frac{.69 F_{ty} t^2}{C} \quad (\text{REF. LOCKHEED STRESS MEMO \#89})$$

t = FLG. THICKNESS C = ECCENTRICITY

$$P_{ULT.} = \frac{.69 \times 54000 \times .25^2}{.375} = 6200^{\#} \quad P_{YLD} = 4130^{\#}$$

EFFECTIVE FLANGE WIDTH " b "

$$\frac{6 M_{YLD}}{b t^2} = F_{ty} \quad \frac{6 \times 4130 \times .375}{b (.25)^2} = 54000 \quad (\text{REF. MILHDBK 5})$$

$$b = \frac{6 \times 4130 \times .375}{54000 \times .0625} = 2.76"$$

$$\text{DEFL. } \delta = \frac{P C^3}{3 E I} = \frac{4130 \times .375^3 \times 12}{3 \times 10.3 \times 10^6 \times 2.76 \times .25^3} = .00198"$$

$$K_2 = \frac{4130}{.00198} = \underline{\underline{2,090,000^{\#}/IN.}}$$

BEAM 3 (FRONT)

FLANGE THICKNESS $t = .25$, $C = .78$

$$P_{ULT.} = \frac{.69 \times 54000 \times .25^2}{.78} = 3000^{\#} \quad P_{YLD} = 2000^{\#}$$

EFFECTIVE FLANGE WIDTH " b "

$$\frac{6 M_{YLD}}{b t^2} = F_{ty} \quad \frac{6 \times 2000 \times .78}{(b) .25^2} = 54000 \quad b = 2.76"$$

$$\text{DEFL. } \delta = \frac{P C^3}{3 E I} = \frac{2000 \times .78^3 \times 12}{3 \times 10.3 \times 10^6 \times 2.76 \times .25^3} = .00853$$

$$K_2 = \frac{2000}{.00853} = \underline{\underline{235,000^{\#}/IN.}}$$

ALSEP FASTENER REDUCTION STUDY

COMPUTER INPUT DATA FOR MOMENTS & DEFLECTIONS

EXISTING PALLET - SEE PAGES 7 & 13 FOR
LETTER DESIGNATIONS.

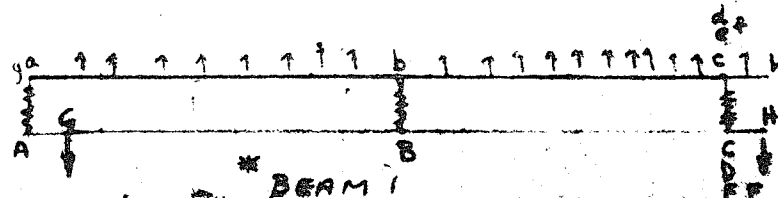
W = 1.0 #/IN

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| BEAM | $EI_1 \times 10^6$ | $EI_2 \times 10^6$ | $K_1 \times 10^6$ | K_2 | GH | gh | GA | ga | ab=AB | bc=BC | cd=CD | de=DE | FH | fh |
|------|--------------------|--------------------|-------------------|-------|-------|-------|------|------|-------|-------|-------|-------|------|------|
| 1 | .2035 | 5.5424 | .860 | 16900 | 18.60 | 20.60 | 1.70 | 3.00 | 9.30 | 5.00 | — | — | 2.60 | 3.30 |
| 2 | | 5.5424 | .860 | 16900 | 23.00 | 23.40 | 3.75 | 4.20 | 4.70 | 5.65 | 5.75 | — | 3.25 | 3.10 |
| 3 | | 6.9224 | .640 | 1870 | 26.20 | 26.27 | 4.90 | 5.00 | 7.00 | 2.90 | 4.50 | 2.75 | 4.10 | 4.10 |
| 4 | | 5.5424 | .860 | 16900 | — | — | — | — | — | — | — | — | — | — |
| 5 | .2035 | 5.5424 | .860 | 16900 | — | — | — | — | — | — | — | — | — | — |

PALLET REVISION No. 1

| BEAM | $EI_1 \times 10^6$ | $EI_2 \times 10^6$ | $K_1 \times 10^6$ | $K_2 \times 10^6$ | GH | gh | GA* | ga | ab=AB | bc=BC | cd=CD | de=DE | FH | fh |
|------|--------------------|--------------------|-------------------|-------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 1* | .2035 | 5.5424 | .860 | 2.090 | 18.60 | 19.6 | 1.861 | 0 | 9.80 | 9.80 | — | — | .976 | 1.230 |
| 2 | | 5.5424 | .860 | 2.090 | 23.13 | 23.50 | 1.825 | 2.42 | 11.74 | 7.40 | — | — | 2.165 | 2.000 |
| 3 | .3530 | 6.9226 | .640 | .235 | 26.20 | 26.27 | .930 | 1.180 | 12.94 | 11.94 | — | — | 1.426 | 1.180 |
| 4 | | 5.5424 | .860 | 2.090 | — | — | — | — | — | — | — | — | — | — |
| 5 | .2035 | 5.5424 | .860 | 2.090 | — | — | — | — | — | — | — | — | — | — |



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COMPUTER INPUT DATA FOR MOMENTS & DEFLECTIONS

PALLET REVISION NO. 2

| BEAM | $EI_1 \times 10^6$ | $EI_2 \times 10^6$ | $K_1 \times 10^6$ | $K_2 \times 10^6$ | q_H | q_h | q_A | q_a | $ab=AB$ | $bc=BC$ | $cd=CD$ | $de=DE$ | f_H | f_h |
|------|--------------------|--------------------|-------------------|-------------------|-------|-------|-------|-------|---------|---------|---------|---------|-------|-------|
| 1 | 3150 | 5.5424 | .860 | 2.090 | 18.60 | 19.6 | 1.861 | — | 9.80 | 9.80 | — | — | .976 | 1.230 |
| 2 | 3150 | 5.5424 | .860 | 2.090 | 23.13 | 23.56 | 1.825 | 2.42 | 11.74 | 7.40 | — | — | 2.165 | 2.000 |
| 3 | 3530 | 6.9226 | .640 | .235 | 26.60 | 26.27 | .930 | 1.180 | 11.94 | 11.94 | — | — | 1.426 | 1.180 |
| 4 | 3150 | 5.5424 | .860 | 2.090 | — | — | — | — | — | — | — | — | — | — |
| 5 | 3150 | 5.5424 | .860 | 2.090 | — | — | — | — | — | — | — | — | — | — |

$$K = \frac{62.090 \times .860}{10 \times 2.090 + .860} = 6093 \times 10^6 \text{ FOR BEAMS 1, 2, 4, 5 } \left. \vphantom{\frac{62.090 \times .860}{10 \times 2.090 + .860}} \right\} \text{ PALLET REVISIONS 1 \& 2}$$

$$K = \frac{640 \times .235}{10 \times .640 + .235} = .1719 \times 10^6 \text{ FOR BEAM 3}$$

$$K = 10^6 \times \frac{.016900 \times .860}{.016900 + .860} = .016480 \times 10^6 \text{ FOR BEAMS 1, 2, 4, 5 } \left. \vphantom{10^6 \times \frac{.016900 \times .860}{.016900 + .860}} \right\} \text{ EXISTING PALLET}$$

$$K = 10^6 \times \frac{.001870 \times .640}{.001870 + .640} = .001868 \times 10^6 \text{ FOR BEAM 1}$$

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 PROJECT NO. _____
 WORK ALSEP

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UNIT MOMENTS & DEFLECTIONS

COMPUTER INPUT DATA ~ BEAM STIFFNESSES

EXISTING PALLET ~ BEAM 1

| PALLET ~ $EI = .2035 \times 10^6$ | | | LOWER STRUCTURE ~ $EI = 5.5424 \times 10^6$ | | | | | |
|-----------------------------------|---------|--------|---------------------------------------------|--------|--------|--------------------------------|--------|--------|
| MEM. STIFF. | ab | bc | END MEMBERS | | | CENTER MEMBERS | | |
| | | | MEM. STIFF. | GA | FH | MEM. STIFF. | AB | BC |
| e | 9.30 | 5.00 | e | 1.70 | 2.60 | e | 9.30 | 5.00 |
| $2EI/e$ $\times 10^{-6}$ | .0438 | .08140 | $3EI/e$ $\times 10^{-6}$ | 9.7801 | 6.3951 | $2EI/e$ $\times 10^{-6}$ | 1.1916 | 2.2170 |
| $4EI/e^2$ $\times 10^{-6}$ | .08750 | .1628 | $3EI/e^2$ $\times 10^{-6}$ | 5.7527 | 2.4596 | $4EI/e^2$ $\times 10^{-6}$ | 2.3832 | 4.4339 |
| $6EI/e^3$ $\times 10^{-6}$ | .01412 | .0488 | $3EI/e^3$ $\times 10^{-6}$ | 3.3837 | .9461 | $6EI/e^3$ $\times 10^{-6}$ | .3845 | 1.3302 |
| $12EI/e^3$ $\times 10^{-6}$ | .003035 | .0195 | — | — | — | $12EI/e^3$ $\times 10^{-6}$ | .0827 | .5321 |

EXISTING PALLET ~ BEAM 2

| PALLET ~ $EI = .2035 \times 10^6$ | | | | LOWER STRUCTURE ~ $EI = 5.5424 \times 10^6$ | | | | | |
|-----------------------------------|-------|--------|-------|---------------------------------------------|--------|--------|-------------------------------|--------|--------|
| MEM. STIFF. | ab | bc | cd | CENTER MEMBERS | | | END MEMBERS | | |
| | | | | AB | BC | CD | MEM. STIFF. | GA | FH |
| e | 4.70 | 5.65 | 5.75 | 4.70 | 5.65 | 5.75 | e | 3.70 | 4.70 |
| $2EI/e$ $\times 10^{-6}$ | .0866 | .0720 | .0708 | 2.3584 | 1.9620 | 1.9278 | $3EI/e$ $\times 10^{-6}$ | 4.4943 | 5.1960 |
| $4EI/e^2$ $\times 10^{-6}$ | .1732 | .1441 | .1416 | 4.7168 | 3.9240 | 3.8556 | $3EI/e^2$ $\times 10^{-6}$ | 4.8584 | 1.6238 |
| $6EI/e^3$ $\times 10^{-6}$ | .0553 | .03825 | .0369 | 1.5054 | 1.0417 | 1.0056 | $3EI/e^3$ $\times 10^{-6}$ | .7823 | .5075 |
| $12EI/e^3$ $\times 10^{-6}$ | .0235 | .01354 | .0128 | .6405 | .3688 | .3498 | — | — | — |

EXISTING PALLET ~ BEAM 3

| PALLET ~ $EI = .2035 \times 10^6$ | | | | | LOWER STRUCTURE ~ $EI = 6.9226 \times 10^6$ | | | | | | |
|-----------------------------------|-------|-------|-------|-------|---------------------------------------------|--------|--------|---------|-------------------------------|--------|--------|
| MEM. STIFF. | ab | bc | cd | de | CENTER MEMBERS | | | | END MEMBERS | | |
| | | | | | AB | BC | CD | DE | MEM. STIFF. | GA | FH |
| e | 7.00 | 2.90 | 4.50 | 2.75 | 7.00 | 2.90 | 4.50 | 2.75 | e | 4.95 | 4.10 |
| $2EI/e$ $\times 10^{-6}$ | .0581 | .1403 | .0904 | .1480 | 1.9779 | 4.7138 | 3.0767 | 5.0347 | $3EI/e$ $\times 10^{-6}$ | 4.1950 | 5.0652 |
| $4EI/e^2$ $\times 10^{-6}$ | .1162 | .2806 | .1808 | .2960 | 3.9558 | 9.3476 | 6.0834 | 10.0694 | $3EI/e^2$ $\times 10^{-6}$ | .8473 | 1.2355 |
| $6EI/e^3$ $\times 10^{-6}$ | .0249 | .1452 | .0603 | .1615 | .8477 | 4.9389 | 2.0510 | 5.4982 | $3EI/e^3$ $\times 10^{-6}$ | .1712 | .3014 |
| $12EI/e^3$ $\times 10^{-6}$ | .0071 | .1001 | .0268 | .1174 | .2422 | 3.4059 | .9112 | 3.9941 | — | — | — |

ALSEP FASTENER REDUCTION STUDY - UNIT MOMENTS & DEFLECTIONS - COMPUTER DATA - BEAM STIFFNESSES

PALLET REVISION 1

PALLET REVISION 2

PALLET - EI: 2035 x 10⁶ LOWER STRUCTURE - EI: 5.5424 x 10⁶PALLET - EI: 3150 x 10⁶ LOWER STRUCTURE - EI: 5.5424 x 10⁶

| MEM. STIFF. | ab | bc | CENTER MEM. | | END MEMBERS | | | MEM. STIFF. | ab | bc | CENTER MEM. | | END MEMBERS | | |
|-----------------------------------|--------|--------|-------------|--------|----------------------------------|--------|---------|-----------------------------------|---------|---------|-------------|--------|----------------------------------|--------|---------|
| | | | AB | BC | MEM. STIFF. | GA | FH | | | | AB | BC | MEM. STIFF. | GA | FH |
| E | 9.80 | 9.80 | 9.80 | 9.80 | E | 1.861 | .976 | E | 9.80 | 9.80 | 9.80 | 9.80 | E | 1.861 | .976 |
| $\frac{2EI}{l^3} \times 10^{-6}$ | .0415 | .0415 | 1.1311 | 1.1311 | $\frac{2EI}{l^3} \times 10^{-6}$ | 8.9339 | 17.0361 | $\frac{2EI}{l^3} \times 10^{-6}$ | .0642 | .0642 | 1.1311 | 1.1311 | $\frac{2EI}{l^3} \times 10^{-6}$ | 8.9339 | 17.0361 |
| $\frac{4EI}{l^3} \times 10^{-6}$ | .0830 | .0830 | 2.2622 | 2.2622 | $\frac{3EI}{l^3} \times 10^{-6}$ | 4.8006 | 17.4550 | $\frac{4EI}{l^3} \times 10^{-6}$ | .1285 | .1285 | 2.2622 | 2.2622 | $\frac{3EI}{l^3} \times 10^{-6}$ | 4.8006 | 17.4550 |
| $\frac{6EI}{l^3} \times 10^{-6}$ | .0127 | .0127 | .3462 | .3462 | $\frac{3EI}{l^3} \times 10^{-6}$ | 2.5796 | 17.8842 | $\frac{6EI}{l^3} \times 10^{-6}$ | .01966 | .01966 | .3462 | .3462 | $\frac{3EI}{l^3} \times 10^{-6}$ | 2.5796 | 17.8842 |
| $\frac{12EI}{l^3} \times 10^{-6}$ | .00259 | .00259 | .0707 | .0707 | — | — | — | $\frac{12EI}{l^3} \times 10^{-6}$ | .004009 | .004009 | .0707 | .0707 | — | — | — |

PALLET - EI: 2035 x 10⁶ LOWER STRUCTURE - EI: 5.5424 x 10⁶PALLET - EI: 3150 x 10⁶ LOWER STRUCTURE - EI: 5.5424 x 10⁶

| MEM. STIFF. | ab | bc | CENTER MEM. | | END MEMBERS | | MEM. STIFF. | ab | bc | CENTER MEM. | | END MEMBERS | | | |
|-----------------------------------|---------|--------|-------------|--------|----------------------------------|--------|----------------|-----------------------------------|---------|-------------|--------|-------------|----------------------------------|--------|--------|
| | | | AB | BC | MEM. STIFF. | GA | | | | FH | AB | BC | MEM. STIFF. | GA | FH |
| E | 11.74 | 7.40 | 11.74 | 7.40 | E | 1.825 | 2.165 | E | 11.74 | 7.40 | 11.74 | 7.40 | E | 1.825 | 2.165 |
| $\frac{2EI}{L^2} \times 10^{-6}$ | .03467 | .0550 | .9442 | 1.4979 | $\frac{3EI}{L^2} \times 10^{-6}$ | 9.1101 | 7.6801 | $\frac{2EI}{L^2} \times 10^{-6}$ | .0537 | .0851 | .9442 | 1.4979 | $\frac{3EI}{L^2} \times 10^{-6}$ | 9.1101 | 7.6801 |
| $\frac{4EI}{L^2} \times 10^{-6}$ | .06934 | .1100 | 1.8884 | 2.9958 | $\frac{3EI}{L^2} \times 10^{-6}$ | 4.9918 | 3.3466 | $\frac{4EI}{L^2} \times 10^{-6}$ | .1073 | .1703 | 1.8884 | 2.9958 | $\frac{3EI}{L^2} \times 10^{-6}$ | 4.9918 | 3.3466 |
| $\frac{6EI}{L^2} \times 10^{-6}$ | .00885 | .02230 | .2411 | .6072 | $\frac{3EI}{L^2} \times 10^{-6}$ | 2.7352 | 1.6267 | $\frac{6EI}{L^2} \times 10^{-6}$ | .0137 | .03452 | .2411 | .6072 | $\frac{3EI}{L^2} \times 10^{-6}$ | 2.7352 | 1.6267 |
| $\frac{12EI}{L^2} \times 10^{-6}$ | .001509 | .00602 | .0408 | .1630 | — | — | — | $\frac{12EI}{L^2} \times 10^{-6}$ | .002536 | .00982 | .0408 | .1630 | — | — | — |

PALLET - EI: 3530 x 10⁶ LOWER STRUCTURE - EI: 6.9226 x 10⁶PALLET - EI: 3530 x 10⁶ LOWER STRUCTURE - EI: 6.9226 x 10⁶

| MEM STIFF. | ab | bc | CENTER MEM | | END MEMBERS | | MEM STIFF. | ab | bc | CENTER MEM | | END MEMBERS | | | |
|-------------------------------------------|--------|--------|------------|--------|------------------------------------------|---------|---------------|-------------------------------------------|--------|------------|---------------|-------------|------------------------------------------|---------|--------|
| | | | AB | BC | MEM STIFF. | GA | | | | FH | MEM STIFF. | GA | FH | | |
| E | 11.94 | 11.94 | 11.94 | 11.94 | E | .930 | 1.426 | E | 11.94 | 11.94 | 11.94 | 11.94 | E | .930 | 1.426 |
| 2EI/E X 10 ⁻⁶ | .0598 | .0591 | 1.1595 | 1.1595 | 3EI/E ² X 10 ⁻⁶ | 4.1980 | .5065 | 2EI/E X 10 ⁻⁶ | .0591 | .0591 | 1.1595 | 1.1595 | 3EI/E ² X 10 ⁻⁶ | 4.1950 | .5065 |
| 4EI/E X 10 ⁻⁶ | .1182 | .1182 | 2.3190 | 2.3190 | 3EI/E ² X 10 ⁻⁶ | 8.4730 | 1.2355 | 4EI/E X 10 ⁻⁶ | .1182 | .1182 | 2.3190 | 2.3190 | 3EI/E ² X 10 ⁻⁶ | 8.4730 | 1.2355 |
| 6EI/E ² X 10 ⁻⁶ | .01486 | .01486 | .2913 | .2913 | 3EI/E ³ X 10 ⁻⁶ | 17.1200 | 3.0135 | 6EI/E ² X 10 ⁻⁶ | .01486 | .01486 | .2913 | .2913 | 3EI/E ³ X 10 ⁻⁶ | 17.1200 | 3.0135 |
| 12EI/E ² X 10 ⁻⁶ | .00249 | .00249 | .0488 | .0488 | — | — | — | 12EI/E ² X 10 ⁻⁶ | .00249 | .00249 | .0488 | .0488 | — | — | — |

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 BY JALSEP
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 MODEL ALSEP

ALSEP FASTENER REDUCTION STUDY

LOADS & DEFLECTIONS OF EDGE MEMBERS

APPLIED FORCES: (REF. 3 PAR. 4.22 PG. 124)

$$Q_1 = f_{ga} + f_{ab} = w(ga) + w\left(\frac{ab}{2}\right)$$

$$Q_2 = +m_{ga} - m_{ab} = w \frac{(ga)^2}{2} - w \frac{(ab)^2}{12}$$

$$Q_3 = f_{ba} + f_{bc} = \frac{w(ba)}{2} + \frac{w(bc)}{2}$$

$$Q_4 = m_{ba} - m_{bc} = \frac{w(ba)^2}{12} - \frac{w(bc)^2}{12}$$

$$Q_5 = f_{cb} + f_{fh} = w\left(\frac{cb}{2}\right) + w(fh)$$

$$Q_6 = m_{cb} - m_{fh} = \frac{w(cb)^2}{12} - \frac{w(fh)^2}{2}$$

EXISTING PALLET

$$\text{BEAM 1} \sim Q_1 = 7.65^*, Q_2 = -2.71^*, Q_3 = 7.15^*, Q_4 = 5.13^*, Q_5 = 5.80^*, Q_6 = -3.36^*$$

$$\text{BEAM 2} \sim Q_1 = 6.55^*, Q_2 = 6.98^*, Q_3 = 5.175^*, Q_4 = -0.821^*, Q_5 = 5.700^*, Q_6 = -0.93^*$$

$$Q_7 = 5.975^*, Q_8 = -2.055^*$$

$$\text{BEAM 3} \sim Q_1 = 8.52^*, Q_2 = -8.52^*, Q_3 = 4.95^*, Q_4 = -3.38^*, Q_5 = 3.70^*, Q_6 = -9.9^*$$

$$Q_7 = 3.625^*, Q_8 = +1.06^*, Q_9 = 5.475^*, Q_{10} = -7.77^*$$

REVISIONS 1 & 2

$$\text{BEAM 1} \sim Q_1 = 4.90^*, Q_2 = -8.00^*, Q_3 = 9.80^*, Q_4 = 0, Q_5 = 6.13^*, Q_6 = 7.24^*$$

$$\text{BEAM 2} \sim Q_1 = 8.29^*, Q_2 = -8.54^*, Q_3 = 9.57^*, Q_4 = 6.96^*, Q_5 = 5.70^*, Q_6 = 2.56^*$$

$$\text{BEAM 3} \sim Q_1 = 7.15^*, Q_2 = -11.20^*, Q_3 = 11.94^*, Q_4 = 0, Q_5 = 7.15^*, Q_6 = 11.20^*$$

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ALSEP FASTENER REDUCTION STUDY

LOADS & DEFLECTIONS OF EDGE MEMBERS - SAMPLE COMPUTER OUTPUT DATA

BEAM 1
 EXISTING
 PALLET

| NO. * | SLOPES & DEFLECTIONS | | INT. LOADS & MOMENTS | |
|-------|----------------------|-------------------------|----------------------|-----------------------|
| 1 | γ_{a2} | 0.5624×10^{-3} | F_{a2} | -0.8502×10^1 |
| 2 | θ_{a2} | 0.8086×10^{-4} | M_{a2} | -0.2710×10^1 |
| 3 | γ_{b1} | 0.6620×10^{-3} | F_{b1} | 0.8502×10^1 |
| 4 | θ_{b1} | 0.6117×10^{-4} | M_{b1} | 0.3504×10^1 |
| 5 | γ_{b2} | 0.6620×10^{-3} | F_{b2} | 0.3458×10^0 |
| 6 | θ_{b2} | 0.6117×10^{-4} | M_{b2} | 0.1626×10^1 |
| 7 | γ_{c1} | 0.4914×10^{-3} | F_{c1} | -0.3458×10^0 |
| 8 | θ_{c1} | 0.8459×10^{-7} | M_{c1} | -0.3360×10^1 |
| 9 | γ_{a1} | 0.7303×10^{-4} | F_{a1} | -0.7735×10^1 |
| 10 | γ_{a1} | 0.5424×10^{-4} | F_{a1} | 0.7735×10^1 |
| 11 | γ_{b1} | 0.2543×10^{-3} | F_{b1} | -0.6719×10^1 |
| 12 | γ_{b1} | 0.6620×10^{-3} | F_{b1} | 0.6719×10^1 |
| 13 | γ_{c1} | 0.1185×10^{-3} | F_{c1} | -0.6146×10^1 |
| 14 | γ_{c1} | 0.4914×10^{-3} | F_{c1} | 0.6146×10^1 |
| 15 | γ_{a1} | 0.7303×10^{-4} | F_{a1} | 0.1071×10^2 |
| 16 | θ_{a1} | 0.4123×10^{-4} | M_{a1} | 0.1669×10^2 |
| 17 | γ_{a2} | 0.7303×10^{-4} | F_{a2} | -0.2971×10^1 |
| 18 | θ_{a2} | 0.4123×10^{-4} | M_{a2} | -0.1669×10^2 |
| 19 | γ_{b1} | 0.2543×10^{-3} | F_{b1} | 0.2971×10^1 |
| 20 | θ_{b1} | 0.9980×10^{-5} | M_{b1} | 0.4434×10^2 |
| 21 | γ_{b2} | 0.2543×10^{-3} | F_{b2} | 0.3748×10^1 |
| 22 | θ_{b2} | 0.9980×10^{-5} | M_{b2} | -0.4434×10^2 |
| 23 | γ_{c1} | 0.1185×10^{-3} | F_{c1} | -0.3748×10^1 |
| 24 | θ_{c1} | 0.4153×10^{-4} | M_{c1} | 0.2560×10^2 |
| 25 | γ_{c2} | 0.1185×10^{-3} | F_{c2} | 0.9894×10^1 |
| 26 | θ_{c2} | 0.4153×10^{-4} | M_{c2} | 0.2561×10^2 |

* NO. REFERS TO COMPUTER OUTPUT DATA

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 Mechanical Engineering

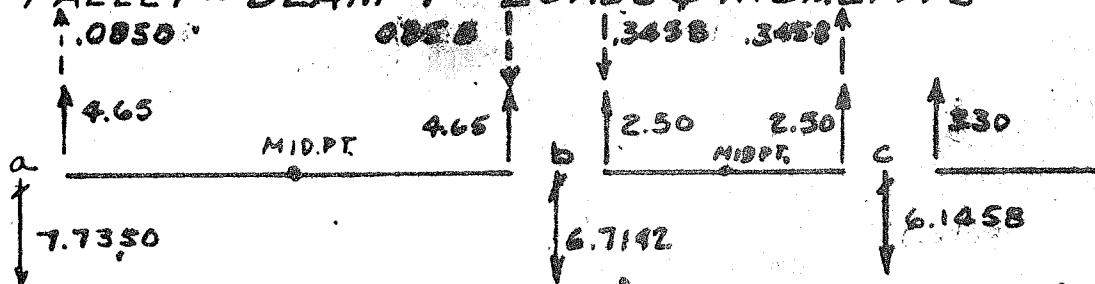
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ALSEP FASTENER REDUCTION STUDY

EXISTING PALLET ~ BEAM 1 ~ LOADS & MOMENTS *

SAMPLE DATA

APPL.
 LOADS 3.00
 REACTIONS



APPL.
 MOMENTS

4.5

7.21
 2.71

2.21

2.2063

2.00
 1.6263

2.00

2.44

REACTING
 MOMENTS 4.5

4.5

3.7063

3.7063

5.44

5.44

DEFLECTIONS AT MID POINTS

$$a b \quad \delta = - \frac{1}{EI} \left[(M_1 + M_2) \frac{l^2}{16} - \frac{5wl^4}{384} \right]$$

$$= -4.914 \times 10^{-6} \left[8.2063 \left(\frac{9.3^2}{16} \right) - \frac{5(9.3)^4}{384} \right]$$

$$= -4.914 \times 10^{-6} [44.3600 - 97.4025] = \underline{\underline{260.6508 \times 10^{-6}}}$$

b c

$$\delta = -4.914 \times 10^{-6} \left[9.1463 \left(\frac{2.5}{16} \right) - \frac{5(6.25)}{384} \right] =$$

$$\delta = -4.914 \times 10^{-6} [14.2910 - 8.1380] = \underline{\underline{-30.2358 \times 10^{-6}}}$$

$$\delta_s = \frac{81}{8} (4.914 \times 10^{-6}) = 49.7542 \times 10^{-6}$$

$$-80.8562 \times 10^{-6} \times 3 = -242.5686 \times 10^{-6}$$

$$\delta_h = \frac{118,5921}{8} (4.914 \times 10^{-6}) = \underline{\underline{72.8452 \times 10^{-6}}}$$

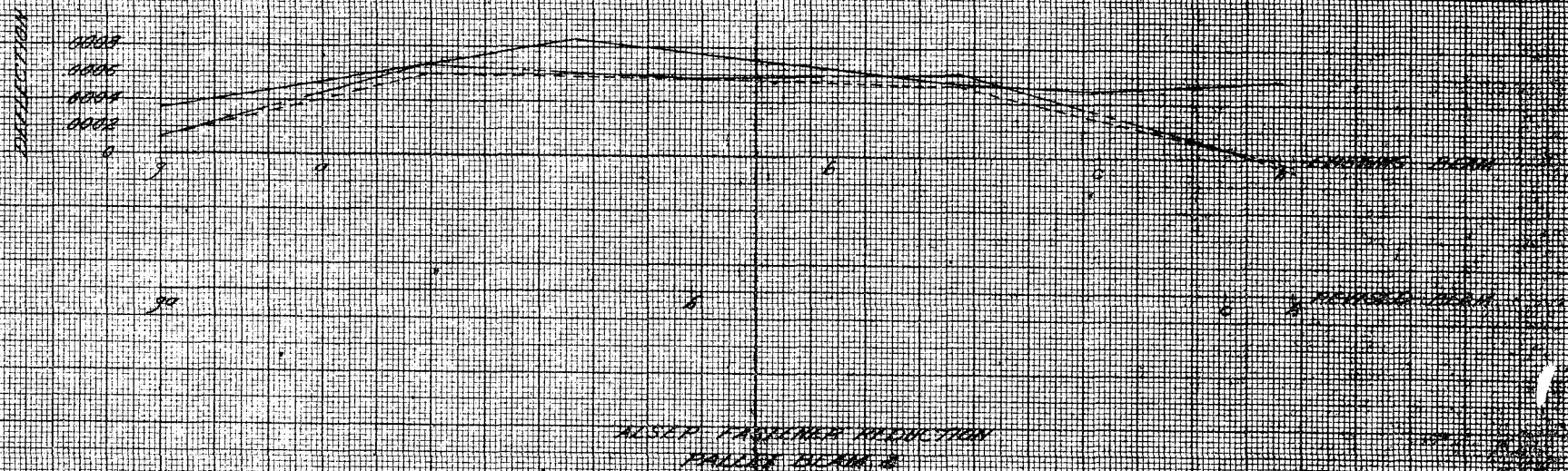
$$.084891 \times 10^{-6} \times 3.3 = .2791 \times 10^{-6}$$

$$\underline{\underline{73.1243 \times 10^{-6}}}$$

* REF. COMPUTER OUTPUT DATA & REF(3) PG. 128

PALLET EDGE MEMBER DEFLECTIONS FROM COMPUTER OUTPUT DATA

LEGEND
EXISTING PALLET
REVISION 1
REVISION 2



PALLET EDGE MEMBER DEFLECTIONS FROM COMPUTER OUTPUT DATA

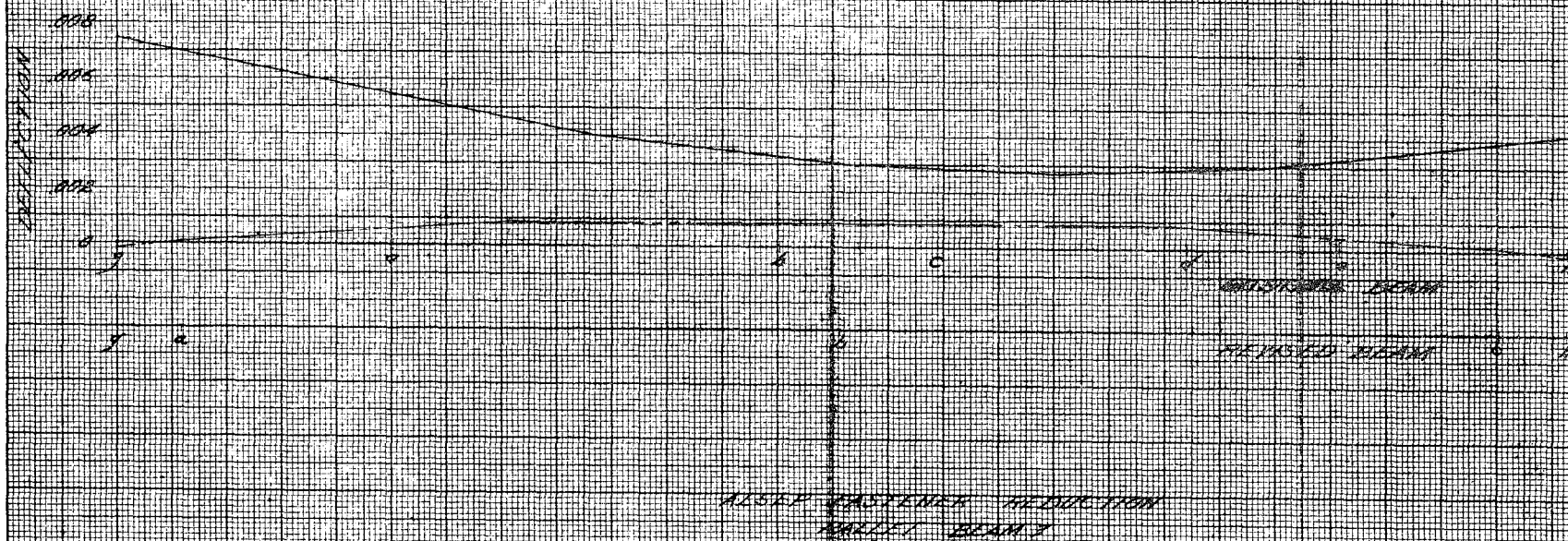
LEGEND
EXISTING PALLET
REVISION 1
REVISION 2



PALLET EDGE MEMBER DEFLECTIONS FROM COMPUTER OUTPUT DATA

LEGEND
 — EXISTING PALLET
 - - - REVISION 1
 - - - REVISION 2

NOTE
 REVISION 1 & 2 IDENTICAL



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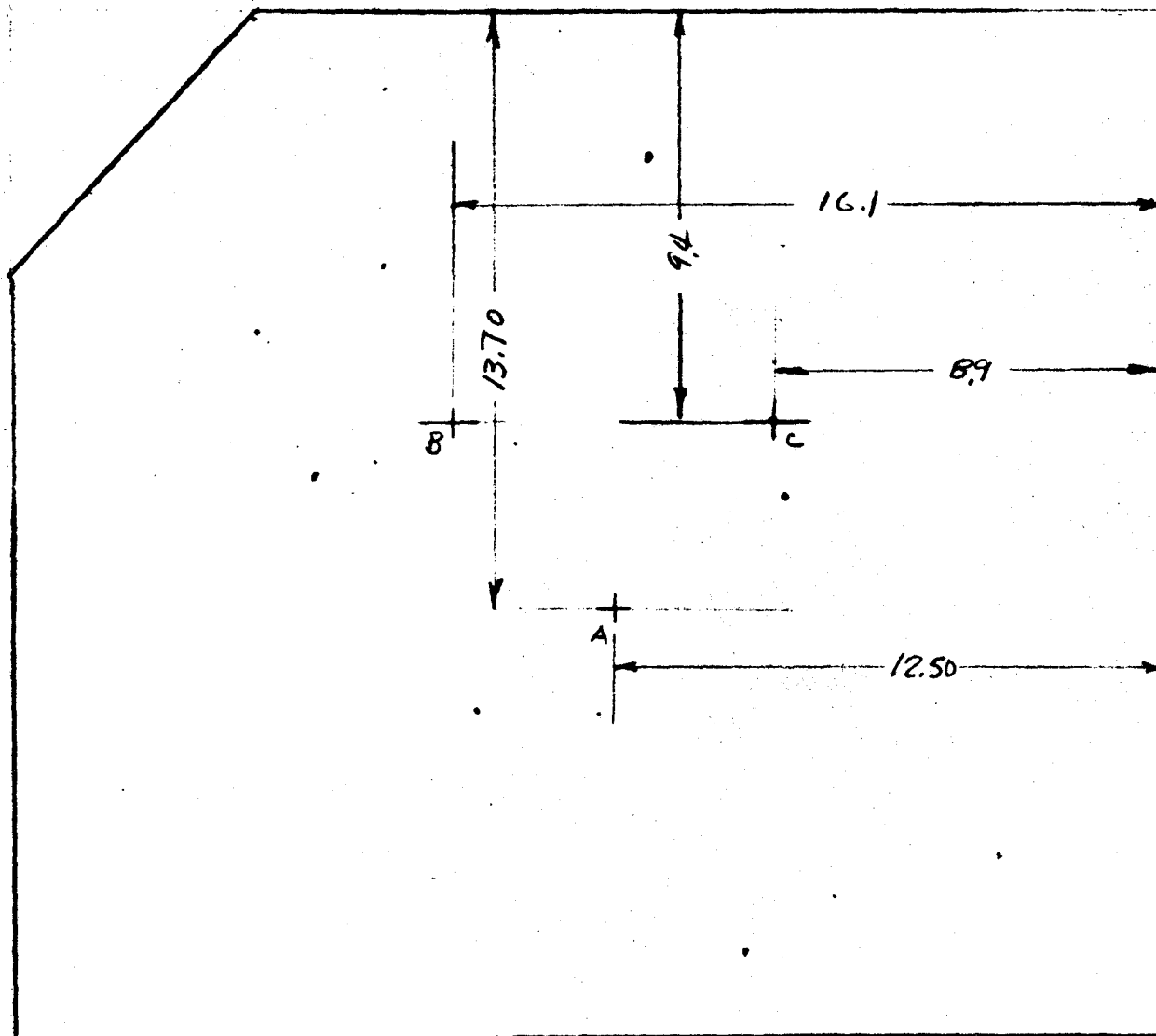
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MODEL ALSEP

ALSEP FASTENERS REDUCTION STUDY

EFFECT ON PALLET OF REMOVING FASTENER FROM
CENTER.

FASTENER PATTERN ~ EXISTING



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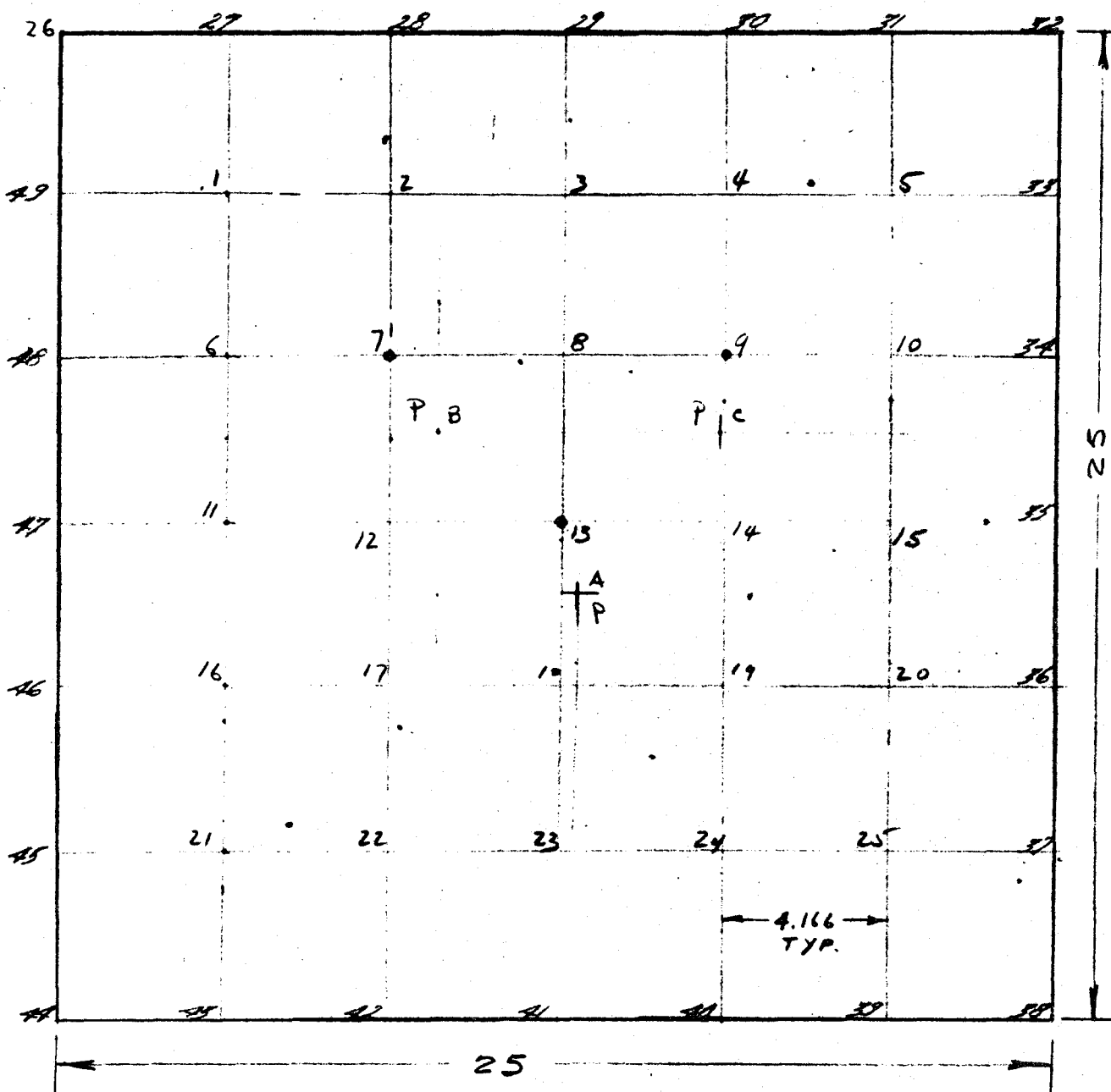
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ALSEP FASTENERS REDUCTION STUDY

EFFECT ON PALLET OF REMOVING FASTENER FROM
CENTER

ASSUMED PALLET & FASTENERS

REF. (2) ENG. RES. BULL. 118 OKLAHOMA STATE UNIVERSITY



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ALSEP FASTENERS REDUCTION STUDY

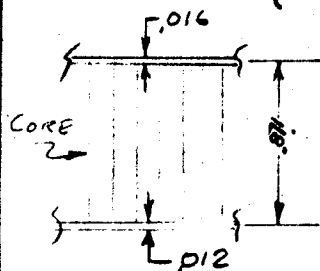
EFFECT ON SUNSHIELD PALLET OF REMOVING ONE
 FASTENER FROM CENTER OF PALLET.

EFFECTIVE PLATE THICKNESS "t"

$$\text{ELEMENTAL } I_{\text{PALLET}} = .016 \times 435^2 + .012 (-435)^2 - .028 (.0620)^2$$

$$= .00302 + .00227 - .0000108 = .00528$$

$$\text{C.G.} = \left(\frac{.016 - .012}{.016 + .012} \right) \left(\frac{871}{2} \right) = .0620$$



$$\frac{t^3}{12} = .00528$$

$$t = \sqrt[3]{.0635} = .40$$

FIND DEFL. FOR "P" AT 7, 9, & 13. ASSUMING PLATE
 SHOWN ON PRECEDING PAGE

REF (12) BULL. NO. 119 "ANALYSIS OF FLAT PLATES BY THE
 ALGEBRAIC CARRY OVER METHOD."

SAMPLE CALCULATIONS:

$$P_{kl} = 1 \quad L_x = L_y = 4.166$$

$$\delta_{xy}^{kl} = \eta_{xy}^{kl} \frac{(1 - \nu^2)}{3 E t^3} P_{kl} L_x L_y$$

$$= \eta_{xy}^{kl} \frac{.91}{3 \times 10.3 \times 10^6 \times .40^3} (1) (4.166)^2 = \eta_{xy}^{kl} (7.9440 \times 10^{-6})$$

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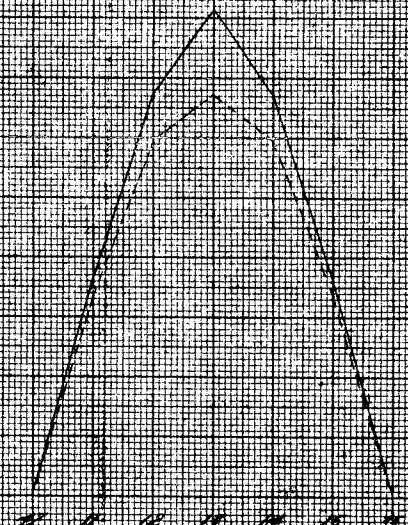
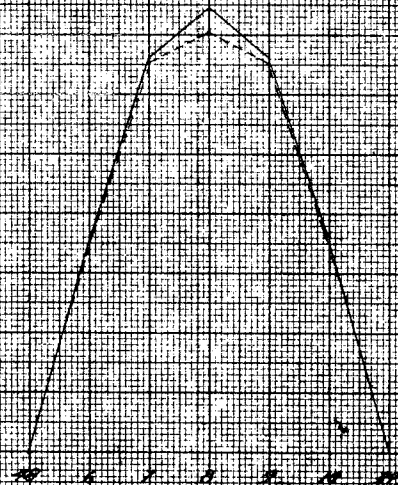
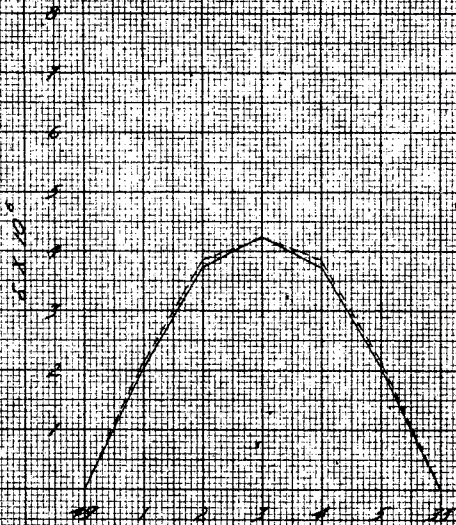
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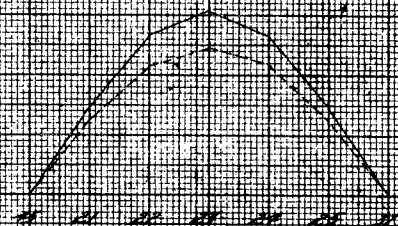
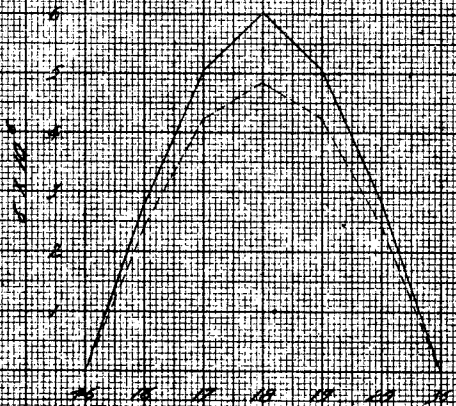
ALSEP FASTENERS REDUCTION STUDY - PALLET DEFLECTIONS

| R. | EXISTING PALLET | | | | | | REMOVE P ₁₅ | | | |
|----|--------------------|---------------------------|--------------------|---------------------------|---------------------|----------------------------|---------------------------|---------------------------|----------------------------|----------------------------|
| | P ₇ = 1 | | P ₉ = 1 | | P ₁₈ = 1 | | N | | REMOVE P ₁₅ | |
| | n | $\delta_{K7} \times 10^6$ | n | $\delta_{K9} \times 10^6$ | n | $\delta_{K18} \times 10^6$ | $\delta_{K7} \times 10^6$ | $\delta_{K9} \times 10^6$ | $\delta_{K18} \times 10^6$ | $\delta_{K15} \times 10^6$ |
| 1 | .1163 | .9239 | .0607 | .4822 | .0827 | .6570 | 2.0631 | 1.3854 | .7233 | 2.1092 |
| 2 | .1967 | 1.5626 | .1221 | .9700 | .1509 | 1.1987 | 3.7313 | 2.3439 | 1.4550 | 3.7989 |
| 3 | .17712 | 1.4069 | .1771 | 1.4069 | .1819 | 1.4450 | 4.2588 | 2.1104 | 2.1104 | 4.2208 |
| 4 | .1221 | .9700 | .1967 | 1.5626 | .1509 | 1.1987 | 3.7313 | 1.4550 | 2.3439 | 3.7989 |
| 5 | .0607 | .4822 | .1163 | .9239 | .0827 | .6570 | 2.0631 | .7233 | 1.3854 | 2.1092 |
| 6 | .1967 | 1.5626 | .1001 | .7952 | .1509 | 1.1987 | 3.5568 | 2.3439 | 1.1928 | 3.5367 |
| 7 | .3495 | 2.7764 | .2014 | 1.6000 | .2813 | 2.2346 | 6.6110 | 4.1646 | 2.4000 | 6.5696 |
| 8 | .2468 | 2.3578 | .2468 | 2.3578 | .3491 | 2.7732 | 7.4888 | 3.5367 | 3.5367 | 7.0734 |
| 9 | .2014 | 1.6000 | .3495 | 2.7764 | .2813 | 2.2346 | 6.6110 | 2.4000 | 4.1646 | 6.5446 |
| 10 | .1001 | .7952 | .1967 | 1.5626 | .1509 | 1.1987 | 3.5568 | 1.1928 | 2.3439 | 3.5367 |
| 11 | .1771 | 1.4069 | .1041 | .8270 | .1820 | 1.4450 | 3.6789 | 2.1104 | 1.2405 | 3.3509 |
| 12 | .2468 | 2.3578 | .2032 | 1.6142 | .3491 | 2.7732 | 6.7452 | 3.5367 | 2.4213 | 5.9580 |
| 13 | .2813 | 2.2346 | .2813 | 2.2346 | .4547 | 3.6518 | 8.1210 | 3.3519 | 3.3519 | 6.7038 |
| 14 | .2032 | 1.6142 | .2468 | 2.3578 | .3491 | 2.7732 | 6.7452 | 2.4213 | 3.5367 | 5.9580 |
| 15 | .1041 | .8270 | .1771 | 1.4069 | .1820 | 1.4450 | 3.6789 | 1.2405 | 2.1104 | 3.3509 |
| 16 | .1221 | .9700 | .0810 | .6435 | .1509 | 1.1987 | 2.8122 | 1.4550 | .9653 | 2.4203 |
| 17 | .2014 | 1.6000 | .1539 | 1.2226 | .2813 | 2.2346 | 5.0572 | 2.4000 | 1.8339 | 4.2339 |
| 18 | .2032 | 1.6142 | .2032 | 1.6142 | .3491 | 2.7732 | 6.0016 | 2.4213 | 2.4213 | 4.8426 |
| 19 | .1539 | 1.2226 | .2014 | 1.6000 | .2813 | 2.2346 | 5.0572 | 1.8339 | 2.4000 | 4.2339 |
| 20 | .0810 | .6435 | .1221 | .9700 | .1509 | 1.1987 | 2.8122 | .9653 | 1.4550 | 2.4203 |
| 21 | .0607 | .4822 | .0436 | .3464 | .0827 | .6570 | 1.4856 | .7233 | .5196 | 1.2429 |
| 22 | .1001 | .7952 | .0810 | .6435 | .1509 | 1.1987 | 2.6374 | 1.1928 | .9653 | 2.1581 |
| 23 | .1041 | .8270 | .1041 | .8270 | .1820 | 1.4450 | 3.0490 | 1.2405 | 1.2405 | 2.4810 |
| 24 | .0810 | .6435 | .1001 | .7952 | .1509 | 1.1987 | 2.6374 | .9653 | 1.1928 | 2.1581 |
| 25 | .0436 | .3464 | .0607 | .4822 | .0827 | .6570 | 1.4856 | .5196 | .7233 | 1.2429 |

PALLET CENTER DEFLECTIONS



POINTS OF DEFLECTION*



POINTS OF DEFLECTION*

WASER FASTENERS REDUCTION STUDY

EXISTING PALLET 1 FASTENER
PALLET WITH 1 FASTENER DIMINISHED

REFER TO CHARTS 34 & 35 FOR PALLET
FOR FIGURES AND LOCATION OF
DEFLECTIONS

PALLEY CENTER DISRUPTION